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ABSTRACT

The neutron radiative capture cross-sections for the stable isotopes $^{146,148,150}Nd$ were measured by the activation method as a function of neutron energy between 0.5 and 2.2 MeV. Enriched samples were irradiated with neutrons from the $^{3}H(p,n)^{3}He$ reaction using a Van de Graaff accelerator. The measurements were made with respect to the $^{197}Au(n,\gamma)^{198}Au$ and $^{115}In(n,n')^{115}In^{m}$ reactions.

Neodymium isotopes are important in nuclear reactor engineering as fission products which absorb neutrons in the reactor core. The yield of the isotopes $^{146,148,150}Nd$ - thermal neutron-induced ^{235}U fission products - is 3%, 1.7% and 0.7% respectively. The accuracy required at present for the neutron radiative capture cross-sections for neodymium nuclei is 10% in the 0-1 MeV range. A substantial number of values for these cross-sections were obtained by calculation with an uncertainty of the order of 50%. In the energy range studied here (0.5-2.2 MeV) the neutron radiative capture cross-sections for the $^{148,150}Nd$ nuclei were measured by Johnsrud and co-workers [1]. Belanova and co-workers [2] consider that the data in Ref. [1] should be renormalized to new values of the reference cross-sections for thermal neutron radiative capture. At present there are no experimental data on the cross-sections for the $^{146}Nd(n,\gamma)^{147}Nd$ reaction.

In this study we used the activation method to measure the (n,γ) reaction cross-sections for neodymium isotopes in the 0.5-2.2 MeV energy range relative to the reference cross-sections for the ^{115}In(n,n')^{115}In^{m} and ^{197}Au(n,γ)^{198}Au reactions. In order to increase the measurement accuracy during irradiation, we used enriched neodymium isotopes, whose composition is given in Table 1. Samples in the form of (Nd_2O_3) powder were compressed into discs 6 mm in diameter with a mass of 6-50 mg, and packed in thin (4 mg/cm^2) polyethylene film. The mass of the samples was determined by weighing. The neutrons were obtained from the ^{3}H(p,n)^{3}He reaction by bombarding a solid titanium-tritium target (0.8-1mg/cm^2) with protons accelerated in the Van de Graaff accelerator of the V.G. Khlopin Radium Institute.

The integrated neutron flux was measured from the activation of a detector consisting of isotopes of the reference reaction. Two detectors of indium or gold, 6 mm in diameter and 0.22 mm in thickness, were arranged on two sides close up against the sample. The assembly containing the sample and the respective detectors was placed 12 mm away from the neutron source at an angle of 0° to the proton beam. The irradiation time for $^{148,\,150}$Nd was the half-life of the reaction product, and that for ^{146}Nd was 14 hours.

The gamma spectra of the irradiated samples were identified and measured by a gamma spectrometer with a 38 cm^3 Ge(Li) detector. The main features of the irradiation method, gamma activity measurement and cross-section calculation are described in Ref. [3]. The characteristics of the product nuclei from the reactions studied and the reference reactions are given in Table 2.

The results of these measurements and the values of the reference reaction cross-sections are given in Table 3, which also shows the total root-mean-square error of the cross-section measurement. The neutron energy scatter given in the first column of Table 3 is due to proton energy losses in the titanium-tritium targets and to the solid angle of the sample relative to the neutron source.

The results of our experimental investigations of the neutron radiative capture cross-sections for ^{146}Nd are shown in Fig. 1, while those for ^{148,150}Nd are shown in Figs 2 and 3, which also give the data from Ref. [1].

Figure 4 shows an example of the use of isotope systematics [8] to evaluate the unknown neutron radiative capture cross-section for ^{144}Nd at 0.5 MeV. The measurement results from the present study were used as reference cross-sections. According to the evaluation, the cross-section of the (n,γ) reaction for ^{144}Nd at E_n = 0.5 MeV is 80(10) mb.

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Table 1.

Mass and isotopic composition of samples

Isotope	Chemical compound	Mass of sample in terms of element, mg	Isotopic composition
^{146}Nd	Nd_2O_3	30-50	142-0,46; 144-0,68; 154-0,49; 146-97,4; 148-0,55; 150-0,12.
^{148}Nd	-	6-14	142-1,21; 143-0,84; 141-1,55; 146-1,58; 148-93,2; 150-1,07.
^{150}Nd	-	30	142-0,97; 143-0,76; 144-1,58; 146-1,41; 148-0,67; 150-94,0

Table 2.

Characteristics of product nuclei from reactions studied and reference reactions [4, 5, 6]

Reaction	Half-life	Eγ, keV	Quantum yield, %
$^{146}Nd(n,\gamma)^{147}Nd$	10,98(1) days	91,1	28,2(3)
$^{148}Nd(n,\gamma)^{149}Nd$	1,725(7) h	211,31	23,4(5)
$^{150}Nd(n,\gamma)^{151}Nd$	12,44(7) min	116,7	46,5(4)
$^{115}In(n,n')^{115m}In$	4,486(1) h	336,2	45,9(5)
$^{197}Au(n,\gamma)^{198}Au$	2,695(2) days	411,8	95,56(7)

Table 3.

Cross-sections (in millibarns) for the reference reactions $^{197}Au(n,\gamma)^{198}Au$, $^{115}In(n,n')^{115}In^m$ and the reactions $^{146}Nd(n,\gamma)^{147}Nd$, $^{148}Nd(n,\gamma)^{149}In$ and $^{150}Nd(n,\gamma)^{151}Nd$ measured in the present study as a function of neutron energy

$E_n(\Delta E_n)$, MeV	^{197}Au [6]	^{115}In [7]	^{146}Nd	^{148}Nd	^{150}Nd
0,50(13)	134,6	-	55(6)	37,5(5)	26(3)
0,70(13)	101,0	17,7	-	43,5(5)	-
0,80(13)	90,8	30,9	-	36(4)	-
0,90(12)	85,5	50,5	-	33(4)	-
1,100(12)	83,0	64,4	41(5)	33(4)	24(4)
1,20(11)	76,0	112,2	-	26(3)	-
1,30(11)	73,5	132,7	-	22(3)	-
1,40(10)	72,0	158,2	22(3)	-	16(2)
1,50(10)	71,5	180,6	-	23(3)	-
1,60(9)	69,0	192,5	21(3)	22(3)	15(2)
1,80(9)	61,5	221,7	-	24(3)	13(2)
2,00(8)	54,0	268,5	35(6)	21(3)	13(2)
2,20(8)	46,0	307,2	-	15(2)	-

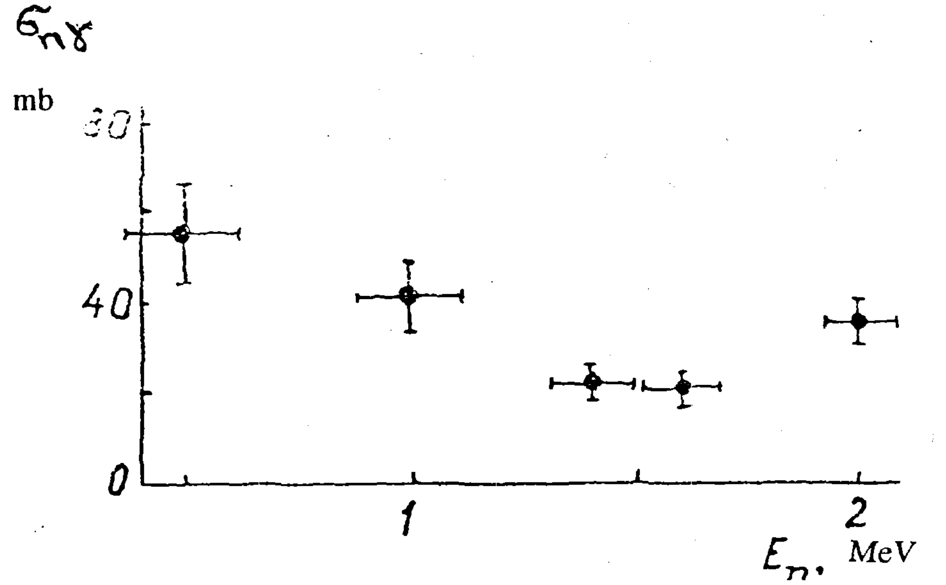

Fig. 1 . Dependence of the cross-section for the $^{146}Nd(n,\gamma)^{147}Nd$ reaction on neutron energy. Data of the present study.

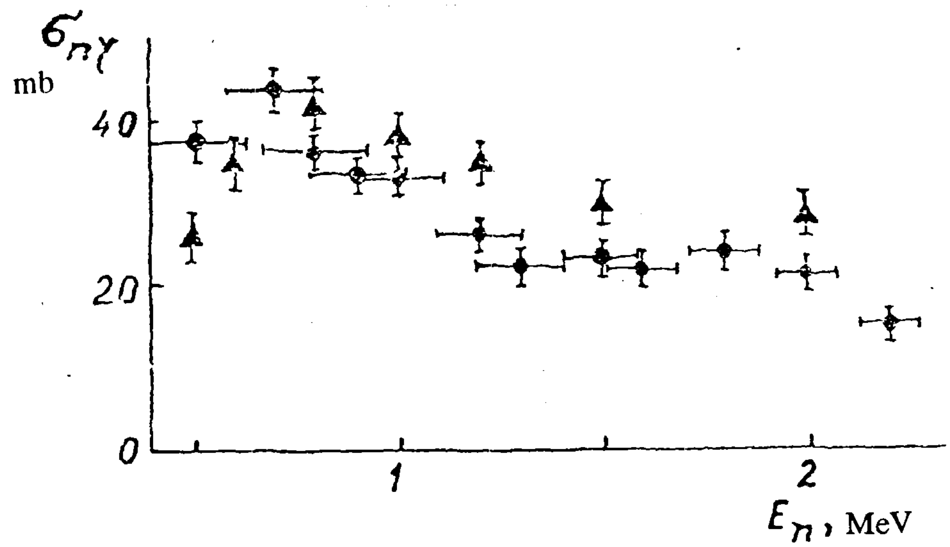

Fig. 2. Dependence of the cross-section for the $^{148}Nd(n,\gamma)^{149}Nd$ reaction on neutron *energy. Data from: ● - present study, ▲ - Ref. [1].*

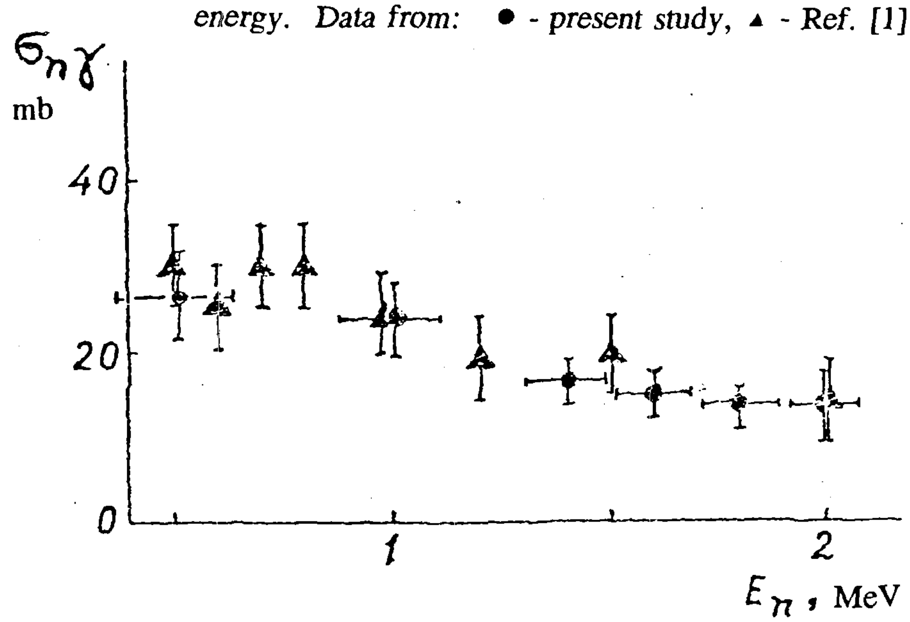

Fig. 3. Dependence of the cross-section for the $^{150}Nd(n,\gamma)^{151}Nd$ reaction on neutron energy. Data from: ● - present study, ▲ - Ref. [1].

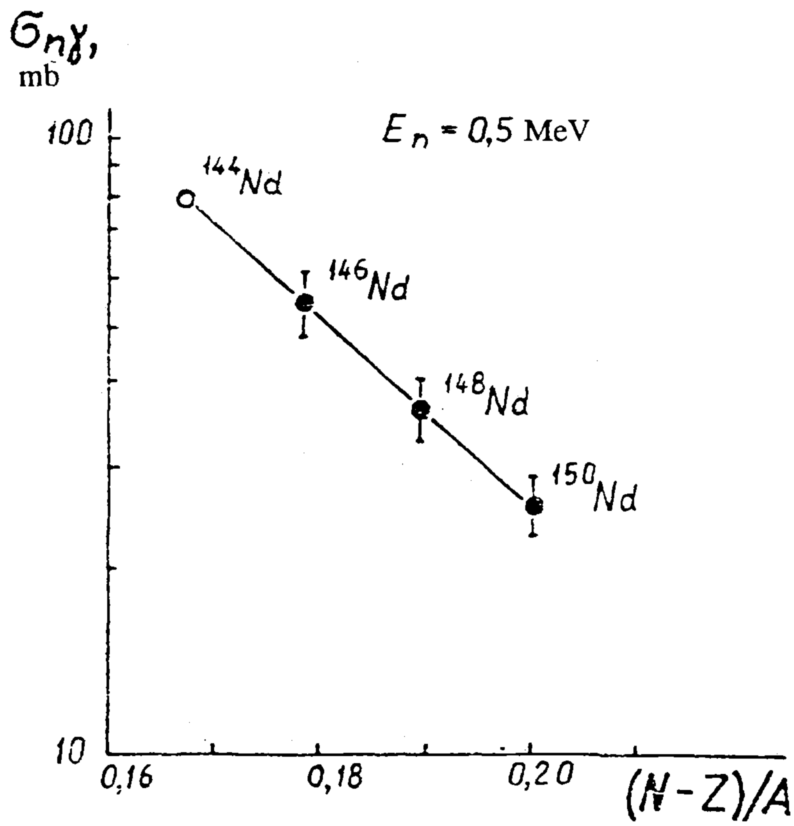

Fig. 4. Isotopic dependence of the neutron radiative capture cross-sections for neodymium isotopes at an energy of 0.5 MeV on the neutron excess parameter (N-Z)/A. Data: ⫯ - experimental data of present study, o - evaluation.

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